Before the

FEDERAL COMMUNICATIONS COMMISSION

Washington, D.C. 20554

In the Matter of	)	
	)	
Revision of Part 15 of the Commission's	)	ET Docket No. 98-153
Rules Regarding Ultra-Wideband	)	
Transmission Systems	)	

REPLY COMMENTS OF FANTASMA NETWORKS, INC.

FANTASMA NETWORKS, INC.
James F. Lovette
Director of Strategic Policies
3250 Ash Street
Palo Alto, CA 94306

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Fantasma Networks, Inc. ("Fantasma") hereby replies to the comments filed on the above-captioned Notice of Proposed Rulemaking ("NPRM").

INTRODUCTION

As evidenced by the comments filed in this proceeding, there is widespread support for amending the Part 15 rules to permit the deployment of ultra-wideband ("UWB") technologies. Public safety groups, educators, medical organizations, groups representing the elderly and disabled, federal and local government agencies, and other potential users and beneficiaries of UWB technologies have filed comments and letters supporting the Commission's proposals. Each of these parties has recognized the numerous benefits of UWB that may be realized from this new broadband transmission technology.

Some parties filed comments addressing technical issues relating to UWB operations. These comments fall into two categories • those that oppose the introduction of UWB technologies below 2 GHz because of safety concerns regarding possible harmful interference to global positioning satellite systems ("GPS") and those that, for commercial reasons, oppose any additional use of the spectrum in which their licensed radio systems operate • even if the new use would pose no realistic threat of harmful interference. Many parties in both categories have expressed interest in the results of tests under way by NTIA[1] that may quantify interactions and identify or refute the possibility of harmful interference effects between UWB transmitters and other devices.

Fantasma has designed its UWB communications technologies to operate above 2 GHz. Fantasma, therefore, confines these reply comments to issues relating to UWB operations above 2 GHz.

As explained below and in the attached Technical Appendix, none of the comments filed in this proceeding undermines the Commission's tentative conclusions regarding the ability of UWB technologies to operate above 2 GHz without causing harmful interference to radio systems in those bands. The Commission should and can, therefore, proceed quickly to adopt service rules under Part 15 for UWB operations above 2 GHz.

DISCUSSION

I. There Is Wide-Ranging Support For The FCC's Proposal To Permit UWB Technologies above 2 GHz Now.

The vast majority of comments filed in this proceeding support operation of unlicensed UWB technologies under Part 15, particularly UWB wireless communications systems being developed for operation above 2 GHz. The parties filing these comments recognize that UWB may hold the key to the development of new broadband technologies that will improve the quality of life for ordinary Americans, particularly for those with special needs. For example, numerous groups representing the disabled, elderly, and medically infirm urge the Commission to move quickly on UWB technology that will provide independence to those with impaired physical abilities.[2] Many of the devices

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[2] E.g., Comments of The Amyothrophic Lateral Sclerosis Association; Comments of the Alzheimer's Association; Comments of the Alliance on Mental Illness; Comments of the American Association of

and services that will be developed for those users will best be implemented above 2 GHz.

Other parties support adoption of UWB rules under Part 15 to foster the development of highly specialized communications technologies to support critical services. The U.S. Navy notes, for example, that UWB technologies "offer the ability to provide a nearly undetectable communications link for covert operations that are typically required for naval maneuvers."[3]

Many others have recognized that UWB wireless communication technology offers a once-in-a-generation opportunity to improve the educational experience to help bridge the "digital divide" that increasingly separates technological "haves" from the "have-nots."[4] Because UWB technologies are capable of providing a low-cost last link for each individual to connect with broadband networks such as the Internet, they can help to bring broadband services to underserved populations that currently are left out of the communications and information revolution.[5]

Finally, several commenting parties, including Fantasma, Xtreme Spectrum, Inc., and Time Domain Corporation, have pointed out the growing consumer need for simple, flexible connection of numerous digital devices to each other within the home and to external broadband networks. UWB communications devices operating above 2 GHz address this need ideally, offering a unique combination of very high data rates, low cost, and wireless mobility.

UWB technologies can, in short, play a vital role in the evolution of existing narrowband wired and wireless facilities into broadband wireless

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People with Disabilities (filed Oct. 12, 2000); Comments of the Disability Rights Education and Defense Fund (filed Oct. 10, 2000).

[3] Comments of the Department of the Navy.

[4] See Comments of Rainbow / PUSH Coalition; see generally "Falling Through The Net: Toward Digital Inclusion," U.S. Department of Commerce White Paper (Oct. 2000).

networks and be the impetus for the development of new, 21st Century communications products and services. For that reason, the Commission should move expeditiously to complete the first stage of this rulemaking and adopt UWB service rules under Part 15, especially UWB communications technologies operating above 2 GHz.

II. Concerns Regarding UWB Operations Above 2 GHz Have Been Overstated.

A number of parties agree with the Commission's conclusion that UWB technologies operating above 2 GHz will pose little or no threat of harmful interference to existing services.[6] Some existing users of the radio spectrum, however, oppose the introduction of UWB into the bands of frequencies for which they are licensed. Although a "not in my backyard" attitude is to be expected, the concerns raised and the remedies proposed regarding UWB operations have been unsupported and overstated.[7]

A. A Few Parties Have Resisted The Introduction Of UWB Technologies Without Providing Any Technical Showing.

A few of the parties that have questioned whether UWB technologies may operate above 2 GHz without causing harmful interference have failed to make any substantial technical showing. Instead, they simply assert that UWB operation will be incompatible with existing radio services. These parties have provided no evidence that they understand UWB principles, no technical analysis of possible inter-reactions between their systems and UWB transmitters,

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[5] See generally Comments of Hewlett-Packard Company.

[6] See, e.g., Comments of XtremeSpectrum, Inc.

[7] One UWB party, MultiSpectral Solutions, Inc. ("MSSI"), raised a concern about interference from "unfiltered" UWB systems. MSSI stated that an antenna should not be assumed to be an effective filter for a transmitted signal because damage to the antenna, or anomalies in the local environment can alter the frequency response of the antenna. Although true, this phenomena is not limited to UWB antennae, but applies to various other types of antennae used by radio technologies as well. See Technical Appendix § I. Accordingly, Fantasma has designed a system that does not rely on antenna filtering to shape the signal. As a regulatory matter, however, the Commission's focus should remain on establishing reasonable and practical out-of-band emissions limits for UWB operations, and not on specifying the means of achieving those limits.

and no specific supporting rationale to which UWB proponents may respond. The Commission, therefore, should discount these unsupported blanket objections.

For example, the National Association of Broadcasters ("NAB") questions the Commission's tentative decision to allow UWB operations above 2 GHz given that broadcasters use the 1.990 GHz to 2.110 GHz band for electronic news gathering ("ENG") operations.[8] NAB does not, however, provide any basis for its supposed concern. Indeed, as NAB itself recognizes, ENG systems use high-gain directional antennas that render ENG transmissions extremely robust and resistant to all forms of interference. The Commission should assume, therefore, absent any technical showing to the contrary, that UWB signaling will not cause harmful interference to ENG operations.

Similarly, the National Business Aviation Association, Inc. ("NBAA") and Rockwell-Collins Inc. ("Rockwell") adopt a "sky-is-falling" posture with regard to UWB operations above 2 GHz. NBAA opposes UWB operations in "any portion of the RF spectrum … due to the absence of data and corresponding analysis of the effects of UWB-generated interference."[9] Rockwell urges the Commission to raise the UWB frequency floor to 5.15 GHz because radio altimeters and microwave landing systems operate in the 4 GHz and 5 GHz bands.[10]

Neither NBAA nor Rockwell, however, has made a showing that UWB would cause any actual harmful interference to the services that they identify, nor have they described reasonable scenarios that would prompt an intuitive response to that effect. Instead, they rely on their own lack of analysis to oppose authorization of UWB above 2 GHz. The Commission should not permit any

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[8] Comments of NAB at 3.
[9] NBAA Comments at 12.
[10] Comments of Rockwell at 5.

obstructionist tactics to delay the introduction of new, innovative UWB technologies. UWB proponents already have demonstrated that UWB transmissions will, as a practical matter, be invisible to other radio services.[11] If any party has a serious concern about harmful interference from UWB operation, it has an obligation to provide at least some minimal technical showing in support of that position, to which UWB proponents may then respond.

B. Those With Technical Objections To UWB Have Based Their Claims On Unrealistic Assumptions Or Incomplete Analysis.

Several parties raise technical objections to the NPRM, either with regard to UWB operations themselves or with regard to the Commission's proposed UWB rules. For example, a number of parties question the Commission's tentative conclusion in the NPRM that "only the closest [UWB] transmitter placing an emission on the frequency of concern would be of importance, obviating the need for additional attenuation to compensate for cumulative effects."[12] Others question some of the Commission's assumptions regarding appropriate UWB power measurements.

In fact, however, in each case, analysis of the technical materials submitted by these parties reveals that the Commission's original conclusions are sound and that the objections raised are based on unrealistic assumptions or incomplete analysis.

1. As a practical matter, emissions from the single closest UWB transmitter will predominate such that UWB aggregation effects will be negligible.

In the NPRM, the Commission tentatively concluded that:

> The cumulative impact [of UWB transmitters] appears to be negligible at the power levels and with the modulation types being proposed, especially when compared to the interference potential from a single land

[11] See, e.g., NPRM ¶¶ 1-6.
[12] NPRM ¶ 47.

> mobile transmitter. This leads us to believe that only the closest transmitter placing an emission on the frequency of concern would be of importance, obviating the need for additional attenuation to compensate for cumulative effects.[13]

AT&T Wireless, Boeing, Cisco, and Rockwell each, in one form or another, questions the Commission's tentative conclusion.[14] Cisco in particular devotes a large part of its technical analysis attempting to demonstrate that it is at least possible, as a theoretical matter, for the calculated level of interference from multiple UWB transmitters to exceed the interference potential of the closest UWB transmitter.

Although it may be possible to describe a theoretical scenario in which the calculated level of cumulative emissions from a mass of UWB transmitterscould become high enough to cause harmful interference, these scenarios simply do not mirror real-world operating environments of today or most likely, even the future. To the contrary, as explained in the attached paper, Understanding Aggregations of Many UWB Emitters, as a practical matter, "the level of harmful interference from a single nearby UWB emitter will dominate the level of interference from an aggregation of millions of emitters scattered throughout a metropolitan area."[15]

According to Dr. Shepard, even when a large number (*e.g.*, millions) of UWB emitters are scattered throughout an area, the potential for the aggregation to raise the noise floor is well bounded and the level of aggregate signals will be comparable to the signal from a single nearby emitter.

[13] NPRM ¶ 47.

[14] See Comments of AT&T Wireless Services, Inc. ("AT&T Wireless") at 6; Comments of The Boeing Company ("Boeing") at 10-15; Comments of Cisco Systems, Inc. ("Cisco") at 11 & Technical Appendix; Rockwell Comments at 5-6.

Normally, a single UWB emitter will be close enough to any victim receiver to produce this eclipsing effect. Dr. Shepard calculates the probability of finding one UWB emitter closer than the characteristic distance of all UWB emitters to be greater than 95%. Indeed, even in in-door environments in which there may be multiple UWB transmitters operating, one would not expect to find a location, as one moves about within the environment, at which a single UWB transmitter would not be the predominate source of UWB emissions. In outdoor environments, in which the distribution of UWB technologies is expected to be less dense, this eclipsing affect will be even more pronounced.

Moreover, the Commission was correct in its conclusion that "[t]he cumulative impact [of UWB] appears to be negligible at the power levels and with the modulation types being proposed, especially when compared to the interference potential from a single land mobile transmitter."[16] In metropolitan areas today, many existing sources of harmful interference including spurious emissions from high-power VHF and UHF transmitters, intermodulation effects (including the incidental mixing of authorized transmissions in metal structures), existing unintentional radiators, and existing incidental radiators already “aggregate” to create an increased level of interference or a raised noise floor. Because the link budget and the number and site selection for central stations of radio systems being designed today already must account for this radio noise, authorizing UWB emissions at levels comparable to these existing non-thermal noise sources will not lead to an “aggregation” problem.

In short, although there may be millions of UWB devices in any metropolitan area, in all realistic scenarios the interference experienced by a receiver can be determined reliably by considering the interference from the nearest single UWB transmitter. There is no basis, therefore, to add a layer of

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[16] NPRM ¶ 47.

complexity to UWB interference analysis by attempting to account for, and factor in, multiple UWB transmitters.

2. **UWB emissions should be measured in the frequency domain with a 1 MHz resolution bandwidth.**

In the NPRM, the Commission asked for comment on a variety of issues relating to UWB measurement procedures. Among other things, the Commission asked for comment on two proposed methods of measurement for UWB technologies: (1) the peak level of emission when measured over a bandwidth of 50 MHz; and (2) the absolute peak output of the emission over the entire UWB bandwidth.[17] The Commission's intent is to "develop measurement procedures that are reasonably simple and straightforward and can apply to a wide range of UWB devices."[18]

Several parties filed comments supporting the adoption of a UWB emission measurement protocol using 50 MHz resolution bandwidth ("RBW"), apparently seeking to provide additional protection from UWB transmissions[19] Others further proposed a time domain-based measurement procedure, apparently with the same protection goal in mind.[20]

The current Part 15 rules include "simple and straightforward" measurement procedures. The measurement technique for Part 15 unlicensed devices involves an average measurement of 1 MHz RBW and 10 Hz video bandwidth ("VBW"). The rules also specify a maximum "peak" emission level, measured in 1 MHz RBW and VBW, of 20 dB higher value than the average measurement.

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[17] NPRM ¶ 42.

[18] NPRM ¶ 49.

[19] E.g., Cisco Comments; Comments of Metricom, Inc. ("Metricom").

[20] See Comments of Lucent.

As set forth below and in Section III of the Technical Appendix, there is no need to change the Part 15 measurement rules for UWB. Indeed, measuring UWB emissions in the frequency domain over 1 MHz bandwidth will provide more accurate information and a more protective standard than the proposed alternatives. The Commission should, therefore, apply current Part 15 measurement protocols to UWB technologies. Such measurements are well understood in the industry and they can be made at most RF testing facilities. They are, therefore, "simple and straightforward," and they provide the requisite degree of accuracy.

3. There is no basis to impose power restrictions on UWB technologies operating above 2 GHz.

A few parties have sought to raise issues relating to possible UWB interference into existing and planned wireless and satellite services in the 2-3 GHz bands.[21] For example, Motorola claims that UWB technologies above 2 GHz should be required to reduce peak power by 12dB below Part 15 standards.[22] Cisco, for its part, claims that the signal fall-off that will occur above 2 GHz will not be fast enough, and that Part 15 offers inadequate protection from harmful interference by UWB devices.[23] However, as set forth in the Technical Appendix, there are a number of problems with these assumptions and with the analysis upon which these parties have drawn their conclusions.

First, the parties advocating a UWB power reduction have based their analysis on path loss models that do not reflect real world operating conditions. For example, the Friis model used by both Cisco and Motorola, provides for path loss in free space. It is not, therefore, useful for predicting actual path loss in

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[21] See Cisco Comments at 3; Comments of Metricom, Inc. (2.3 GHZ WCS band); Comments of XM Radio at 9; Comments of Sirius Satellite Radio Inc. at 10; Comments of Mobile Communications Holdings, Inc. at 3.

[22] Motorola's claim is based on a link budget calculation using two models for path loss: the Hata model and Friis model.

[23] Cisco at 5 ("there is not much of a difference between such losses at 2 GHz and 2.5 GHz").

urban and suburban areas, where the potential for harmful interference is greatest , because such environments typically will include buildings, trees, cars, and other objects that attenuate and diffract UWB signals. The results gleaned from models based on free space path loss, therefore, are unreliable in most real world situations.

Motorola also uses the Hata model, which provides path loss data for more cluttered environments. The Hata model, however, only applies to frequencies from 150 MHz to 1500 MHz, with separation distances from 1 km to 20 km, and base-station heights of at least 30 meters. The predicted loss is 3 dB higher at 2 GHz, and it increases with increasing frequency. Indeed, at 2.5 GHz, more realistic path loss models such as the COST-231 model or a model using a propagation coefficient of 2.8, can give 20-35 dB more attenuation (at a distance of 1 km) than that of path loss in free space.

Based on these more realistic assumptions, the specific concerns of Motorola and Cisco regarding interference with MDS base stations and subscribers are unfounded.

Interference with MDS Base Stations

We agree with the Motorola assumption that it is highly unlikely that a UWB transmitter will be located within 50 meters of an MDS base-station tower. Motorola and Cisco, however, then apply unrealistically pessimistic path-loss models to estimate a 73 meter minimum acceptable separation between a UWB emitter and a victim MDS base station receiver. Using the more realistic path loss models outlined above, we estimate minimum required separation to be from 27 to 35 meters – well within the 50-meter boundary Motorola and Cisco assume. Furthermore, Motorola further overstates the potential for interference by assuming that base stations employ omni-directional antennae. Using a more realistic assumption that base stations may employ directional antennae, potential interference is reduced further still. By factoring in realistic assumptions for both signal path-loss and antenna configuration, we conclude that UWB emitters will not cause any harmful interference to MDS base stations.

Interference with MDS Subscribers

On the subscriber side of an MDS system, Motorola and Cisco again overstate the potential for interference from UWB emitters. As with the calculations for base stations, the Motorola and Cisco calculations for subscriber receivers are based on unrealistic path-loss models, and on the assumption of omni-directional receiver antennae. MDS subscriber receivers often will be located on a rooftop, affixed to the side of a building, or otherwise positioned favorably with respect to the associated base station – a significant isolation from the likely locations of UWB emitters. Losses from building materials and other objects in the local environment will further reduce the potential interference from any nearby UWB transmitters.[24] Furthermore, MDS subscriber antennae generally are high-gain and narrow beam width, rather than omni-directional – a factor that further reduces the potential for interference. Thus, just as in the case of the base-station, the overall potential for UWB interference is substantially lower than the Motorola / Cisco estimates suggest, and the completely arbitrary 12 dB reduction in UWB power proposed by Motorola is not necessary.

In the end, the parties that have expressed concern regarding possible harmful interference from UWB emissions have, at best, shown that it is possible to construct theoretical scenarios in which a particular receiver may experience harmful interference. It is certain, on the other hand, that a significant power reduction on UWB emissions would be highly detrimental to the operation of UWB technologies.

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[24] Motorola also assumes in its analysis a high-gain, omni-directional antenna at the base-station. As discussed in the Technical Appendix, this assumption, too, is highly questionable.

As explained in the Technical Appendix, a power reduction by as much as 12dB, as suggested by Motorola, would reduce the range of a home-networking UWB application by a factor of four. If the range is held constant, alternatively, and the UWB system had a required bit error rate of 10^{-6}, a power reduction of 12 dB would increase the bit error rate to the maximum possible bit error rate of 0.5. Thus, a UWB communications technology previously capable of providing service throughout a home would be limited in range such that it may only be capable of providing adequate service in a single room within the home.

If, on the other hand, the reduced-power UWB technology were forced to provide service throughout the home, the data rate would be so negatively impacted that much of the advantage of using UWB would be lost. Any such dramatic reduction in the utility of, and the variety of applications for, UWB technologies would be contrary to the public interest.

III. UWB Technologies Should Be Authorized Under Part 15.

As the Commission notes in the NPRM, "most near-term applications for UWB technology involve relatively low powers and short operating ranges. Further, … most UWB devices are intended to be mass marketed to businesses and consumers and [therefore] individual licensing of each device would be impractical."[25] Accordingly, the Commission tentatively has determined that it will authorize UWB operation under Part 15. A few parties question that determination.

Sirius, for example, argues that the Commission should adopt some form of blanket licensing mechanism for UWB rather than allowing these technologies to operate on an unlicensed basis. Sirius notes that, unlike Part 15 devices, UWB technologies will "radiate into restricted bands."[26] Similarly, Boeing favors

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[25] NPRM ¶ 18.
[26] See Comments of Sirius at 20-21.

blanket licensing and suggests further that the Commission should impose rules that would limit distribution of UWB technologies to public safety agencies.[27]

The fact that UWB will "radiate" in restricted bands is irrelevant because the nature of that radiation is such that UWB will not cause harmful interference to licensed systems using the spectrum. Indeed, one of the most important greater benefits of UWB is that these technologies can make use of spectrum without occupying the spectrum to the exclusion of others.[28] The technical standards and certification process that will be developed for UWB devices governed by Part 15 will be sufficient to ensure that there is an extremely low probability that UWB technologies will cause harmful interference to other services.

The suggestion that only public safety agencies should have access to new UWB technologies is based on a misconception of the uses and potential for UWB. Boeing, for instance, claims that UWB systems "would not expand the types of services available to the public [but] simply provide a new, but not necessarily more spectrally efficient, means to provide an existing consumer service."[29] Boeing has overlooked the unique capabilities of UWB to deliver high bandwidth services, among other characteristics, to offer new values to education, medical care, and underserved populations, as has been expressed most directly by those who will directly benefit from such applications, as well as to consumers seeking better connectivity.

UWB offers an opportunity for the Commission to promote the first truly 21st Century technology. Because of the nature of UWB emissions and the

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[27] Comments of Boeing at 14. It is not clear from Boeing's comments whether they are meant to address UWB communications technologies as well as UWB radiolocation technologies. To the extent that they are, however, Boeing's comments are based on a fundamental misunderstanding of the nature of UWB and the public benefits that it will yield.

[28] Leander Kahney, The Third generation Gap, Scientific American (Oct. 2000) (the article may be found on-line at http://www.scientificamerican.com/2000/1000issue/1000kahney.html#author).

applications for which UWB is well suited, it is appropriate to authorize the technology on an unlicensed basis under Part 15. By doing so, the FCC will help open a door to the future.

CONCLUSION

For the reasons stated herein and in its initial comments, Fantasma urges the Commission to move expeditiously to complete this rulemaking and permit UWB operations above 2 GHz.

Respectfully submitted,

FANTASMA NETWORKS, INC.

By: /s/James F. Lovette
James F. Lovette

Director of Strategic Policies
3250 Ash Street
Palo Alto, CA 94306
lovette@fantasma.net
web site: www.fantasma.net

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[29] Comments of Boeing at 11.

Appendix 2

Analysis of Interference Issues in MDS and UWB Band Sharing

1. Assumptions on the minimum acceptable separation distance are not valid.

Cisco and Motorola defines the minimum acceptable separation distance (MASD) as follows. If the UWB transmitter is located less than the MASD from the victim MDS receiver, then the noise floor of the victim MDS receiver will be raised by an acceptable amount. Cisco calculates the MASD for a victim MDS subscriber with 20 dBi antenna gain to be 380 meters. Motorola calculates the MASD to be 13 meters for a victim MDS subscriber with –8 dBi antenna gain and 70 meters for a victim MDS base-station with 12 dBi antenna gain. From this distance computation, Motorola computes the probability that a UWB transmitter will be located closer than the MASD and concludes that the power must be decreased by 12 dB.

The calculations of the MASD are highly dependent on the environment. In a typical urban or suburban environment, the signal is affected by diffraction caused by buildings, trees, cars, and “clutter” in the environment that will significantly increase the path loss between a UWB transmitter and a victim receiver. As a result, calculations based on the path loss in free space are very pessimistic. In fact, at 2.5 GHz, more realistic path loss models such as the COST-231 model or a model using a propagation coefficient of 2.8 (denoted “PC=2.8”) can give 20-35 dB more attenuation (at a distance of 1 km) than that of path loss in free space.

Cisco assumes path loss in free space to compute the MASD. Motorola also assumes path loss in free space to compute the MASD between a UWB transmitter and a victim subscriber. For the base-station, Motorola adds 5 dB of “clutter” loss to the path loss in free space. These computations are pessimistic, as shown in the table below.

Antenna Gain (dBi)	Motorola / Cisco MASD	COST-231 MASD	PC=2.8 MASD
-8 dBi subscriber	13 meters	9 meters	6 meters
12 dBi base-station	73 meters	35 meters	27 meters
20 dBi subscriber	380 meters	62 meters	54 meters

Table 1: Minimum acceptable separation distance (MASD) between UWB transmitter and a victim MDS receiver within the main antenna beamwidth

In the MDS application, it is highly improbable that a UWB transmitter will be located within 50 meters of an MDS base-station tower. An MDS subscriber will be located on a rooftop or affixed to the side of a building, at a typical distance of 10 meters from the ground level. In addition, the subscriber antenna will be highly directional with a narrow antenna beamwidth. For a UWB transmitter to be within the half-power beamwidth, it would need to be located some distance above the ground, as depicted in Figure 1. It is likely that there will be losses from a rooftop or wall in between the UWB transmitter and the MDS subscriber, in addition to the "clutter" in the environment. This would further reduce the minimum distance.

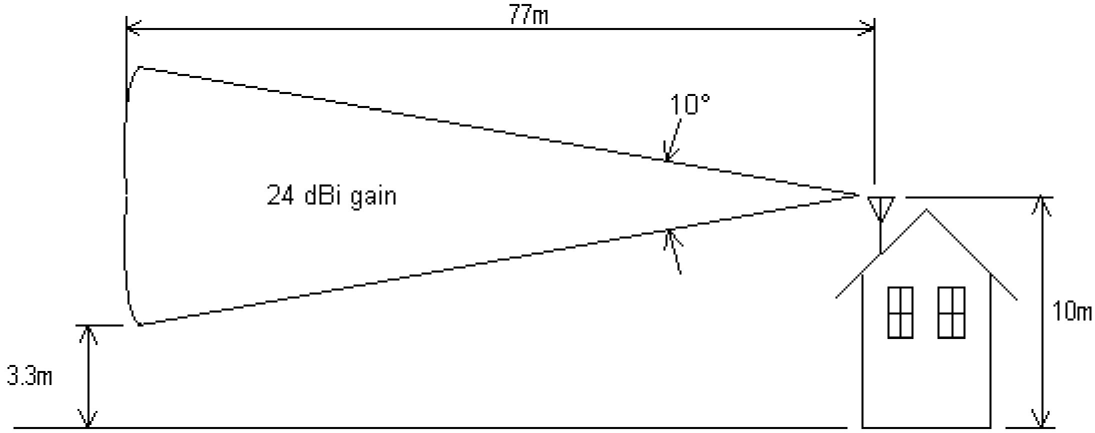

Figure 1: MDS subscriber

2. **There is no need to reduce the power of UWB transmitters.**

Motorola assumes a high-gain omni-directional antenna at the base-station. Such an antenna does not exist, since as the gain of an antenna increases, the antenna beamwidth decreases, as seen in Figure 2. It is more likely that the base-station comprises four receivers, each of which covers a sector of 90 degrees. A 12 dBi antenna might therefore have an azimuth half-power beamwidth (HPBW) of 90 degrees and an elevation HPBW of 20 degrees.

The relationship between gain and beamwidth can be described as follows:

$$Gain = 10 * \log 10\left(\frac{41253 * Eff}{HPBW_{elev} HPBW_{azim}}\right). \quad (1)$$

In the equation above, HPBW denotes the width of the beam in degrees, measured from the –3 dB power points. This is measured in elevation and in azimuth. The variable Eff denotes the efficiency of the antenna and is related to the antenna aperture.

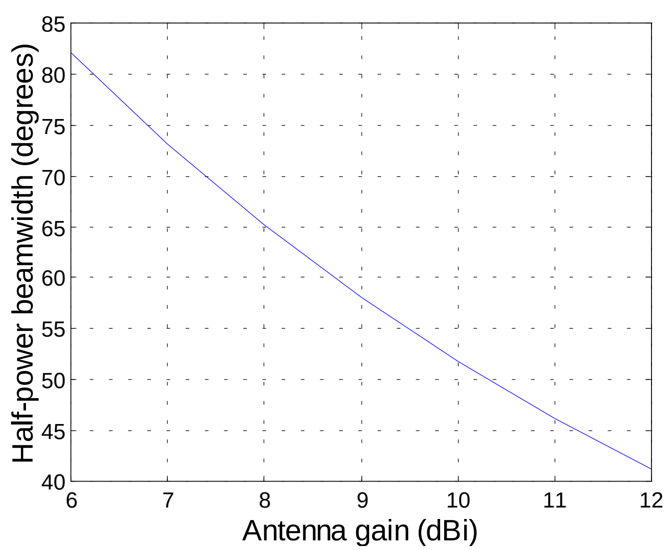

Figure 2: Relationship of Antenna Gain and Directivity if $HPBW_{azim} = HPBW_{elev}$

Suppose the antenna gain drops dramatically outside the HPBW (an idealized situation).

In this case, if we recalculate Motorola's numbers to include only those UWB transmitters located within the HPBW, then the power of the interference is reduced by 6 dB. This is already one half of the 12 dB reduction that Motorola proposes for UWB transmission, and this computation considers only the azimuth HPBW (does not include the elevation HPBW). As seen in Figure 1, the probability that a UWB transmitter will be located in the half-power beamwidth of an MDS subscriber is also small.

We simulated the model system used by Motorola for their analyses. For the subscriber simulation, we use a more realistic antenna gain of 24 dBi with HPBWs of 10 degrees. We assume that UWB transmitters outside the HPBW will not affect the MDS subscriber, and we use the "PC=2.8" channel model up to 1 meter. Under these assumptions, no MDS subscriber is a victim receiver. For the base-station simulation, we assume the same channel model, with the use of an antenna with 90 degree sectors and a height of 150 meters. Under these assumptions, lowering the transmit power by 1 dB decreases the probability of a victim base-station to nothing, as shown in Figure 3. As a result, there is no need to reduce the UWB power by 12 dB.

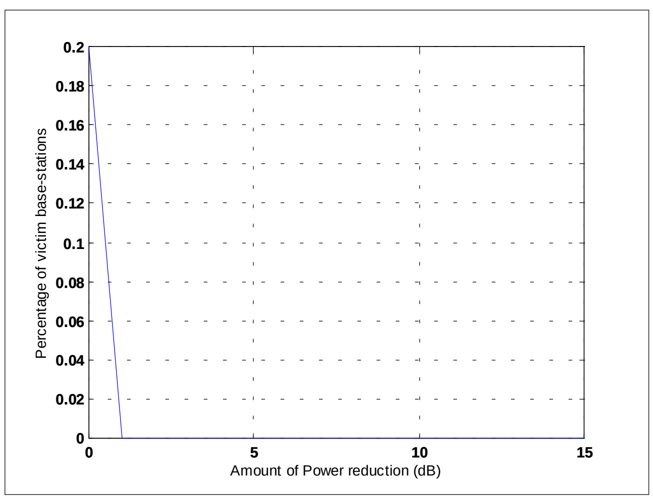

Figure 3: Percentage of victim MDS base-stations

3. 12 dB of power reduction is highly detrimental to UWB systems

Motorola claims that UWB peak power limits should be dropped by 12 dB. This would be highly detrimental to the operation of UWB devices. We can look at the effect on the performance in several different ways. We note that the data rate will drop, the bit error rate will increase, or the maximum distance between two UWB devices (the range) will decrease. These effects are summarized in the table below, where the parameters for the original power were chosen to be similar to those of the first-generation products for Fantasma Networks.

Parameter of Interest	Original power	Power dropped by 12 dB
Data Rate	100 Mbps	6.25 Mbps
Range	150 feet	37 feet
Bit Error Rate	10^{-6}	0.5

If the average power will drop by 12 dB, the data rate will drop by a factor of 16. This can be shown as follows. Suppose a UWB signal has bandwidth W (in Hz), baud period T (in seconds), and it is modulated using binary antipodal modulation, so that ‘0’ is represented by a pulse with unit energy multiplied by A and ‘1’ is represented by a unit energy pulse multiplied by –A. In this case, the average power of the signal is

$$P = \frac{A^2}{T}, \quad (2)$$

and the probability of error is given by

$$\Pr(error) = Q\left(A\sqrt{\frac{2W}{N}}\right), \quad (3)$$

where N is the variance of the added noise. From these equations, we see that if the average signal power drops by 3 dB (a factor of 2), then for the probability of error to remain constant, the baud period must increase by a factor of 2. This means that the pulses must be spaced twice as far apart, which lowers the data rate by a factor of 2. If the average signal power drops by 12 dB, the data rate decreases by a factor of 16.

If the average power drops by 12 dB, the range for a home-networking application drops by a factor of 4, from 150 feet to 37 feet, assuming a free-space path loss, as shown in Figure 4. Suppose the range remains constant and the original UWB system meets a required bit error rate of 10^{-6}. Using Equation (3), if the power drops by 12 dB, the bit error rate increases to the maximum possible bit error rate of 0.5 (a clearly unacceptable bit error rate).

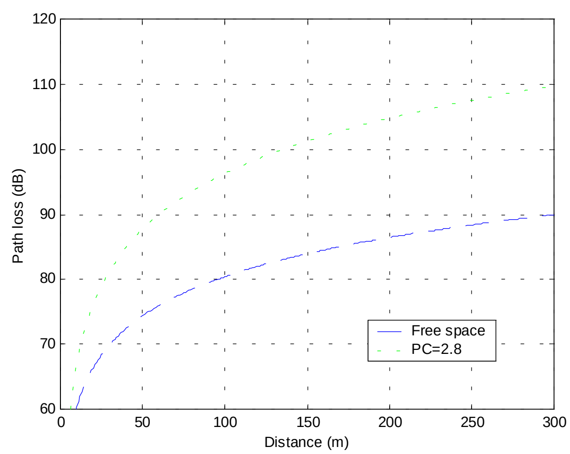

Figure 4: Path loss versus distance